California Environmental Protection Agency

AIR RESOURCES BOARD

PUBLIC MEETING TO CONSIDER APPROVAL OF REVISIONS TO THE STATE'S ON-ROAD MOTOR VEHICLE EMISSIONS INVENTORY

May 2000

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

PUBLIC MEETING TO CONSIDER THE APPROVAL OF CALIFORNIA'S ON-ROAD MOTOR VEHICLE EMISSIONS INVENTORY

BACKGROUND

California's emissions inventory for on-road motor vehicles is an estimate of the amounts and types of pollutants emitted from the millions of vehicles operated in California.

Section 39607(b) of the California Health and Safety Code requires the Air Resources Board, (ARB or Board), to inventory emissions from various sources of air pollution. The ARB has published inventories and updates for over 25 years. Improvements are made periodically to maintain and provide the most complete, accurate, and up-to-date inventory practicable.

As part of this improvement process, the ARB is now proposing to update the existing on-road motor vehicle emissions inventory. This newly revised version, referred to as EMFAC2000, represents a significant change to the existing on-road motor vehicle emissions inventory. The emissions inventory is used to determine the reduction in emissions needed to meet air quality goals, and evaluate the need for and effectiveness of emission control strategies and regulations.

Emission inventories form the basis of clean air plans required under State and federal law. Although our emission inventory is continuously improving, plan revisions are not automatically triggered when a new inventory is approved. Inventory modifications are folded into new plans at appropriate times. For example, the U.S. Environmental Protection Agency is preparing to "bump-up" the San Joaquin Valley to a severe classification with a 2005 attainment date, triggering the need to develop a new clean air plan. If approved by the Board, we will incorporate EMFAC2000 in this plan update.

This report provides a summary of the most important changes to the inventory. In addition to this report, we have prepared a series of documents that presents how the model is constructed, outlines the majority of those modifications that have been made, and assesses the impacts these modifications have on the inventory. Copies of these documents may be obtained from the ARB's Mobile Source Analysis Branch, or downloaded from the ARB's web site at http://www.arb.ca.gov/msei/msei.htm. These documents will compiled into a single, comprehensive Technical Support Document and will be made available no later than ten days prior to the public meeting.

The U.S. Environmental Protection Agency also publishes an on-road motor vehicle emissions inventory model called MOBILE. However, the ARB has long maintained a California specific model. This model better represents conditions unique to California.

ON-ROAD MOTOR VEHICLE EMISSIONS

PROPOSED EMISSIONS INVENTORY

The presentation of EMFAC2000 for approval by the Board represents the culmination of more than ten years of effort on the part of the staff to refine and improve the accuracy of the on-road emissions inventory. This effort began when scientists observed discrepancies between emissions measured in tunnels, and modeled air quality compared to emissions inventory estimates. The monitoring and modeling results indicated that the inventory underestimated emissions from motor vehicles.

The proposed revision to the motor vehicle inventory increases estimated emissions substantially. Therefore, it is important to review the scientific basis for the proposed changes. The section below provides a discussion of the causes for the changes to the inventory, the data upon which the proposed changes are based, and the impacts these changes have on emissions in future years.

The proposed year 2000 and 2010 inventory for each air district is presented in Tables 1 and 2. This represents the reference years from which all projections will be made. The staff will use the approved inventory to produce other types of inventories, such as inventories for past and future years, and inventories used for planning and air quality modeling purposes. Health and Safety Code section 39607.3 requires the Board to periodically review and approve the emissions inventory. Our presentation of the updated inventory is intended to comply with those requirements of the Health and Safety Code. As necessary, we will return to the Board with modifications as new and improved information becomes available.

Recommendation

The staff recommends the Board approve the proposed statewide emissions inventory for on-road motor vehicles. This inventory used the latest available data, analyses, and methodologies to ensure that current year and projected inventories are accurate. In preparing this inventory for Board review, we used the latest in the series of estimation models, referred to as EMFAC2000.

Table 1. –Proposed Emissions Inventory by Air District (Tons per Day in 2000)

DISTRICT	HC	CO	NOx	PM10ex
Amador County APCD	3.1	27.3	3.0	0.07
Antelope Valley APCD	10.5	98.6	11.8	0.19
Bay Area AQMD	248.1	1829.9	263.1	5.75
Butte County APCD	13.1	107.2	11.0	0.30
Calaveras County APCD	4.0	34.2	3.4	0.08
Colusa County APCD	1.5	12.9	2.5	0.07
El Dorado County APCD	9.5	83.2	8.8	0.21
Feather River AQMD	8.6	74.0	8.9	0.25
Glenn County APCD	2.2	18.8	2.5	0.07
Great Basin Unified APCD	3.2	27.1	3.4	0.07
Imperial County APCD	11.3	112.3	13.5	0.30
Kern County APCD	3.7	32.8	3.2	0.08
Lake County APCD	5.6	47.4	4.7	0.10
Lassen County APCD	2.4	21.2	2.4	0.06
Mariposa County APCD	1.7	14.4	1.4	0.03
Mendocino County APCD	7.3	63.2	8.6	0.21
Modoc County APCD	1.0	8.8	1.1	0.03
Mojave Desert AQMD	16.0	140.0	16.4	0.30
Monterey Bay Unified APCD	30.2	246.0	38.5	0.81
North Coast Unified APCD	12.9	107.9	14.4	0.35
Northern Sierra AQMD	8.6	71.0	8.9	0.22
Northern Sonoma County APCD	8.1	69.0	10.2	0.26
Placer County APCD	12.4	109.3	14.1	0.28
Sacramento Metropolitan APCD	54.3	476.5	75.3	1.52
San Diego County APCD	120.7	1049.1	143.2	3.18
San Joaquin Valley Unified APCD	161.3	1563.7	242.9	5.61
San Luis Obispo County APCD	13.7	117.2	15.6	0.37
Santa Barbara County APCD	17.3	143.7	21.7	0.36
Shasta County AQMD	11.7	98.3	10.4	0.33
Siskiyou County APCD	4.9	42.2	4.4	0.11
South Coast AQMD	582.8	5343.7	738.1	16.07
Tehama County APCD	3.8	32.1	3.8	0.11
Tuolomne County APCD	4.8	40.3	4.1	0.10
Ventura County APCD	30.0	260.6	40.2	0.73
Yolo/Solano AQMD	13.2	113.0	24.7	0.48
Statewide	**1443**	**12637**	**1780**	**39**

Table 2. –Proposed Emissions Inventory by Air District (Tons per Day in 2010)

DISTRICT	HC	CO	NOx	PM10ex
Amador County APCD	1.7	13.2	2.0	0.07
Antelope Valley APCD	4.7	45.0	6.2	0.21
Bay Area AQMD	141.2	898.0	148.8	5.10
Butte County APCD	6.6	49.0	6.4	0.28
Calaveras County APCD	2.1	17.0	2.2	0.09
Colusa County APCD	0.8	6.0	1.6	0.06
El Dorado County APCD	4.3	35.0	4.7	0.21
Feather River AQMD	4.6	36.4	5.5	0.24
Glenn County APCD	1.1	8.6	1.6	0.07
Great Basin Unified APCD	1.7	13.1	2.3	0.08
Imperial County APCD	7.2	68.8	12.0	0.30
Kern County APCD	2.1	17.7	2.0	0.09
Lake County APCD	2.8	22.4	3.1	0.11
Lassen County APCD	1.2	9.9	1.7	0.06
Mariposa County APCD	0.9	6.6	0.9	0.03
Mendocino County APCD	3.7	29.4	5.4	0.19
Modoc County APCD	0.5	4.19	1.0	0.03
Mojave Desert AQMD	9.1	73.15	9.8	0.31
Monterey Bay Unified APCD	16.9	123.2	20.8	0.71
North Coast Unified APCD	6.5	49.68	9.2	0.32
Northern Sierra AQMD	4.5	33.6	5.2	0.21
Northern Sonoma County APCD	4.0	31.1	5.8	0.20
Placer County APCD	5.7	47.8	6.7	0.24
Sacramento Metropolitan APCD	24.5	207.2	38.3	1.26
San Diego County APCD	51.9	454.1	68.2	2.92
San Joaquin Valley Unified APCD	69.8	698.3	132.2	5.11
San Luis Obispo County APCD	7.1	56.0	8.5	0.33
Santa Barbara County APCD	9.2	68.8	11.7	0.29
Shasta County AQMD	5.8	45.4	6.3	0.30
Siskiyou County APCD	2.3	18.5	3.0	0.11
South Coast AQMD	252.1	2369.4	396.6	15.51
Tehama County APCD	1.9	14.2	2.1	0.09
Tuolomne County APCD	2.4	18.9	2.6	0.10
Ventura County APCD	12.8	107.7	18.9	0.63
Yolo/Solano AQMD	7.5	58.7	13.1	0.37
Statewide	**681**	**5756**	**966**	**36**

DISCUSSION OF THE PROPOSED EMISSIONS INVENTORY

A preliminary version of EMFAC2000 was discussed at a public workshop held in El Monte in December 1999. Several concerns were raised during that workshop. The need to address and resolve these issues prompted the postponement of the presentation of the revised inventory to the Board. Two major issues were raised at this workshop: (1) the use of chassis dynamometer data to estimate the inventory for heavy-duty trucks; and (2) proposed modifications to the evaporative emissions inventory. Consequently, we used the additional time during the postponement to address other issues as well.

As a result, the inventory presented here differs significantly from what was presented at the December workshop. An account of the major changes to the methodology incorporated between December 1999 and today is included in this report as Appendix A.

The changes made to the modeling methodology in the development of EMFAC2000 are too numerous to discuss in depth in this report. These changes are documented in the Technical Support Document. Table 3 presents a comprehensive list of these changes. However, only those changes that have a major impact on the overall inventory are discussed here. A comparison of the inventory as estimated by MVEI7G model and that proposed using EMFAC2000, is presented by air basin in Appendix B for calendar years 2000 and 2010.

For the sake of clarity, this report will focus on the impact that these changes have on emissions in the South Coast Air Basin (SCAB). It is important to note that because fleet makeup, ambient conditions, and in-use maintenance requirements vary by geographical area, the magnitude of impact will also vary.

Table 3. – New or Revised Features Included in EMFAC2000

ITEM	CATEGORY
County Specific Accrual Rates	Activity
County Specific Reid Vapor Pressure	Emissions
County Specific Registration Distribution	Activity
Hourly Weekday Activity Distribution	Activity
Starts per Vehicle per Day	Activity
Heavy-Duty Activity	Activity
Technology Fractions	Activity
Population/Growth and Survival Rates	Activity
Temperature Correction Factors	Emissions
Hydrocarbon Conversion Factors	Emissions
Carbon Dioxide/Fuel Consumption	Emissions
FTP-to-UC Base Rates	Emissions
Speed Correction Factors	Emissions
HDV Emissions	Emissions
Gasoline Vehicle PM	Emissions
Inspection and Maintenance	Emissions
Fuel Correction Factors	Emissions
A/C Correction Factors	Emissions

Table 3. – New or Revised Features Included in EMFAC2000 (Continued)

Mexican Vehicle Emissions and Activity	Emissions and Activity
Remote Sensing in I/M	Emissions
Humidity Correction Factors	Emissions
Start Correction Factors	Emissions
Evaporative Emissions	Emissions
New Standards	Emissions

Table 4 presents the current and proposed inventory for the South Coast Air Basin (SCAB) for the years 2000 and 2010. Hydrocarbon emissions (HC) increase by 75% in 2000 and more than 65% in 2010. Oxides of nitrogen (NOx) emissions increase by over 30% in 2000 show a slight decrease in 2010. Carbon monoxide (CO) increases by over 85% in 2000, and over 30% in 2010. Exhaust particulate matter less than ten microns in diameter (PM10ex) increases by over 20% in 2000 and 60% in 2010.

Table 4. – Current and Proposed On-Road Emissions Inventory for SCAB

	2000			**2010**		
Pollutant	**7G**	**2000**	**% Change**	**7G**	**2000**	**% Change**
Total HC	326	569	75	147	246	67
CO	2795	5216	87	1753	2311	32
NOx	555	724	30	392	390	-1
PM10 ex	13	16	23	9	15	67

In the following sections, the causes of the increases in estimated emissions will be discussed. The sections are organized by pollutant and the most significant changes are discussed first in each section.

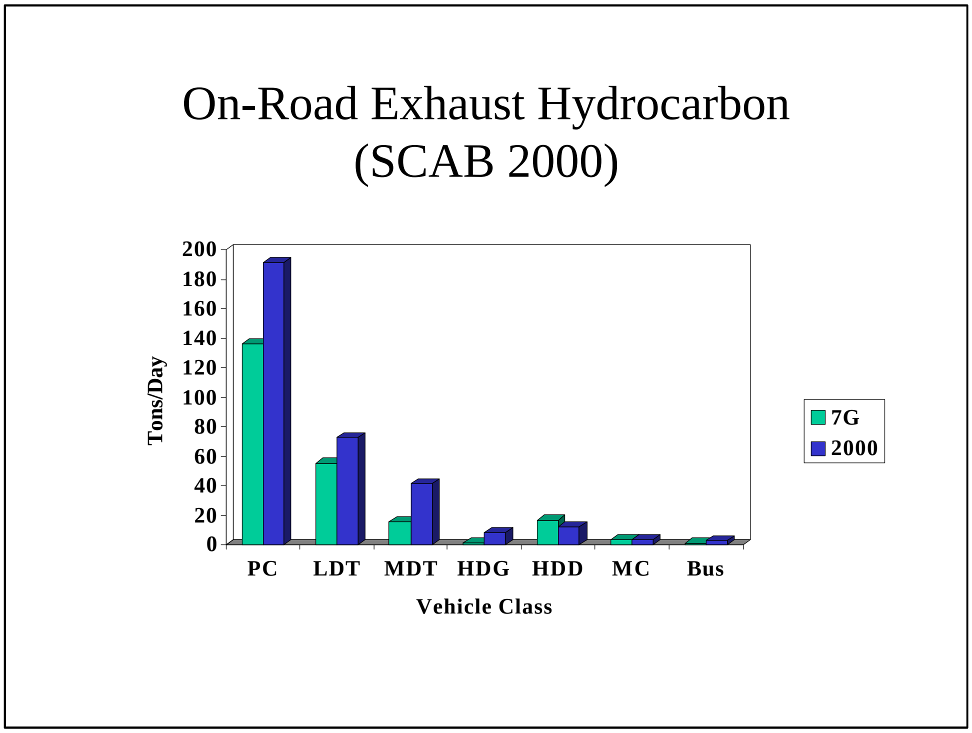
Hydrocarbon Exhaust Emissions

Hydrocarbon exhaust emissions result because not all of the fuel that enters the engine is burned. The unburned fuel is exhausted from the tailpipe. Vehicles with catalytic converters attempt to complete fuel combustion in the exhaust stream before pollutants are released to the atmosphere. Hence, older cars without catalytic converters tend to have higher HC exhaust emissions than newer cars that have catalysts. Efforts to reduce the amount of fuel wasted through incomplete combustion in engines have been successful over the years, primarily through the use of fuel injection systems that more precisely meter the fuel. Similarly, catalysts have been optimized so that they are now over ninety percent efficient.

The connection between the evolution of HC emission control technology and the emissions inventory is that the inventory attempts to reflect the true performance of these technologies in use, with typical customer maintenance, normal and abnormal deterioration of various components, and tampering of emission control systems. Overall HC exhaust emissions are projected by EMFAC2000 to increase by 44 percent compared to the current version of the model, MVEI7G, in the SCAB in year 2000, and by 41percent in the SCAB in year 2010 compared to MVEI7G.

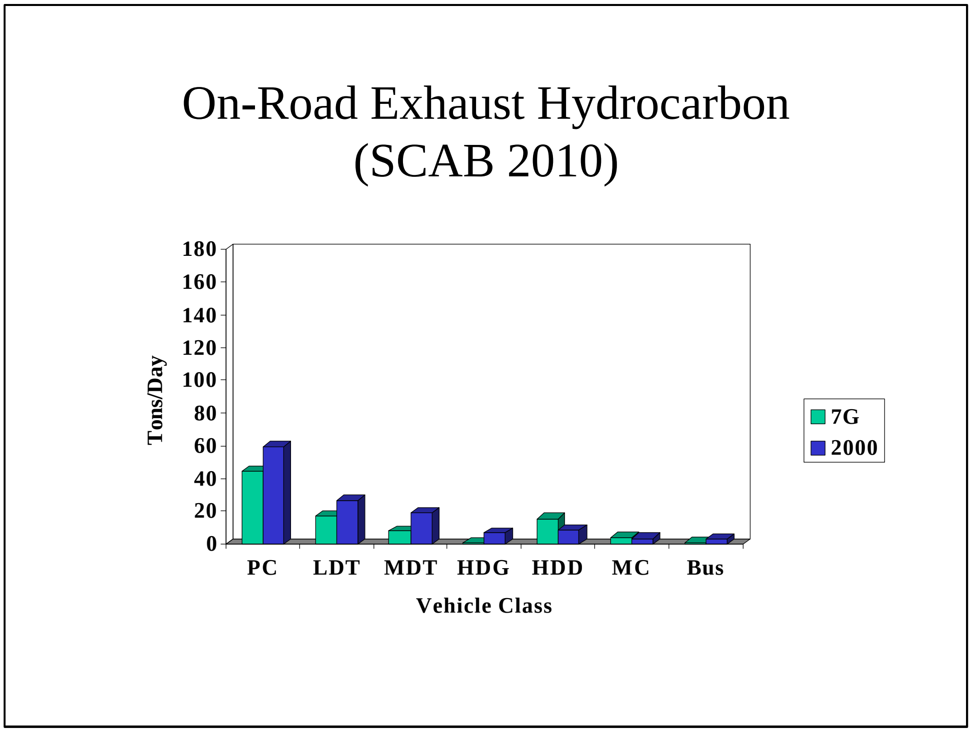
The chart below shows the contribution and distribution of HC exhaust emissions by vehicle class using MVEI7G and EMFAC2000.

Figure 1. – Comparison of MVEI7G and EMFAC2000 for Exhaust HC for 2000



The overall increase in the exhaust hydrocarbon inventory in the SCAB in the year 2000 is 101 tons per day. As can be seen in the figure, ninety-nine percent of the difference is attributable to changes in the emissions estimates of gasoline-powered passenger cars (54%), light-duty trucks (20%) and medium duty vehicles (25%). Vehicles powered by diesel engines are only minor contributors because diesel engines have inherently low HC emissions. Motorcycles are gasoline-powered but are relatively few in number, so they do not contribute significantly to the overall change in the inventory.

Figure 2. – Comparison of MVEI7G and EMFAC2000 for Exhaust HC for 2010



Programs previously adopted by the Board, some of which were not included in MVEI7G, are projected to reduce the inventory of exhaust hydrocarbon by more than half (200 tons per day in the SCAB) by the year 2010. However, at 126 tons per day, exhaust HC emissions are projected to be 37 tons per day higher (41%) compared to MVEI7G projections.

For readers less familiar with emissions inventory estimation methods, an inventory is typically calculated by multiplying the emissions from individual vehicles by how much they are driven and how many there are. The per-vehicle emissions are called "emission factors" and have units of grams per mile. The amount they are driven is called vehicle miles of travel (VMT), and the number of vehicles is referred to as the "population".

Four of the modifications reflected in EMFAC2000 account for 63% of the increase in the HC exhaust inventory for the South Coast Air Basin in the year 2000. These changes are: modifications to the driving cycle adjustments (11%); speed adjustment factors (12%); updates to the emission factors (20%); and changes to the vehicle age distribution (20%). These are discussed in more detail below. The Technical Support Document provides information on other modifications that affect the HC exhaust inventory including new species profiles, RVP correction factors, and the benefits of the Inspection and Maintenance program.

Driving Cycle Adjustments

The Federal Test Procedure (FTP) is the test used for the certification of light-, and medium-duty vehicles, and is the basis for the emission factors (gram per mile estimates of emissions) used in the inventory estimation models. At the core of the FTP is a driving cycle developed in Southern California in the early 1970s. It reflects several compromises that allowed vehicles to be tested on the dynamometers available at that time. Notably, the acceleration rates of the vehicle were limited to avoid any tire slippage on the steel rollers of dynamometers used in the vehicle test cell.

While this deficiency was well known, it took time to develop test equipment capable of properly simulating all vehicle operating modes (large single roll dynamometers). Vehicle operating patterns were also evolving with time, rendering obsolete the driving patterns upon which the FTP was based.

In the early 1990s, a number of vehicle operating pattern studies were performed. These studies revealed that much of contemporary driving is not reflected in the FTP. Since the emissions inventory is supposed to properly represent actual driving, the ARB created a new driving cycle for emissions inventory assessment, called the LA92 or Unified Cycle (UC), which better reflect those higher speeds and accelerations common in today's driving.

In MVEI7G, the large existing database of FTP emissions data was adjusted to a UC basis using correction factors. These correction factors were based on data from approximately 250 vehicles where both FTP and UC tests were performed. Continued testing of vehicles using the UC has produced data on an additional 750 vehicles, which have been included in EMFAC2000. Modifications to the cycle adjustments using this new data increased the emissions estimate for exhaust hydrocarbons by approximately 11%.

Speed Adjustment Factors

The emission factor test cycles, whether they are FTP-based or UC-based, compress an immense range of possible driving conditions into one "average" driving cycle. For example, the UC has an average speed of 27 miles per hour. However, individual vehicles are operated at average speeds far higher (freeway) and lower (traffic jams) than 27 miles per hour.

Emissions vary with speed in a non-linear manner. In order to estimate emissions at other speeds representative of other driving patterns, additional adjustment factors are used. Speed adjustment factors are developed by testing vehicles on the FTP, UC, and various other cycles with different average speeds to develop a curve describing the change in emissions as a function of speed.

In previous versions of the model, thirteen cycles with average speeds ranging from 2.5 to 65 miles per hour were used for this purpose. However, these cycles were not derived from either instrumentation or observation of vehicles, but created by statistically manipulating other cycles. Thus, these synthesized cycles did not represent actual vehicle operation very well.

In the process of creating EMFAC2000, staff developed thirteen new cycles with differing average speeds using subsets of the UC driving data. The emissions from one hundred vehicles were tested using these cycles in order to establish new speed adjustment curves that reflect how emissions change as average driving speeds change. For driving conditions typical of the South Coast Air Basin, the revised adjustment factor increases the exhaust hydrocarbon inventory by approximately 12%.

Exhaust Emission Factors

The database used in the creation of MVEI7G contained information from multiple FTP tests of about 2,600 vehicles and 250 vehicles tested over the UC. The number of vehicles used in development of EMFAC2000 is more than twice that amount and includes 1,000 vehicles tested over both the FTP and the UC. These tests were performed on randomly selected vehicles from Southern California to determine how well emission control systems are working in customer service. Analysis of the larger database suggests higher emission rates than those used previously. This is especially true for older (early 1980s) vehicles that are still prevalent in the fleet. Excluding the changes in driving cycle adjustments discussed earlier, the basic emission rates for light-duty passenger cars increase by 50 to 100 percent in EMFAC2000, depending upon model year, compared to MVEI7G. The changes to the emission factors for exhaust hydrocarbon account for a 20% increase in the inventory.

Vehicle Age Distribution

In updating the emissions inventory, the latest Department of Motor Vehicles (DMV) registration information was analyzed. In MVEI7G, the number of model years of passenger cars assumed to exist in any one calendar year was thirty-five. For all other classes of vehicles, with the exception of motorcycles, MVEI7G accounted for twenty-five model years. Only fourteen model years were carried in MVEI7G for the motorcycle fleet. EMFAC2000 extends the age distribution for all vehicle classes to forty-five. As a result, the average age of the fleet is older in EMFAC2000 compared to MVEI7G. Because emissions are a strong function of vehicle age, the revised age distributions used in EMFAC2000 result in a higher class-specific inventory estimate. Overall, modifications to the vehicle age distribution increase the inventory for exhaust HC by about 20%.

Hydrocarbon Evaporative Emissions

Another source of hydrocarbon emissions is the evaporation and escape of fuel vapors from the tank or engine fuel delivery system into the atmosphere. For modeling purposes, evaporative hydrocarbon emissions are classified into four processes: diurnal; hot soak; running losses; and resting losses.

Diurnal emissions occur when rising ambient temperatures cause fuel evaporation from vehicles sitting throughout the day. Hot soak emissions occur immediately after a vehicle is turned off, due principally to high under-hood temperatures. Running losses occur due to fuel heating and are emitted while the vehicle is being operated. Resting losses, like diurnal emissions, occur when a vehicle is sitting, but are caused by permeation through rubber and plastic components rather than normal daily temperature excursions. In addition to these categories of "normal" emissions from fuel evaporation, emissions can also occur when liquid fuel leaks.

Liquid leaks are not really evaporative emissions. However, because they are primarily associated with failures of the evaporative control system, the model treats liquid leaks as evaporative "high emitters". The emissions associated with liquid leaks are therefore accounted for within all evaporative process.

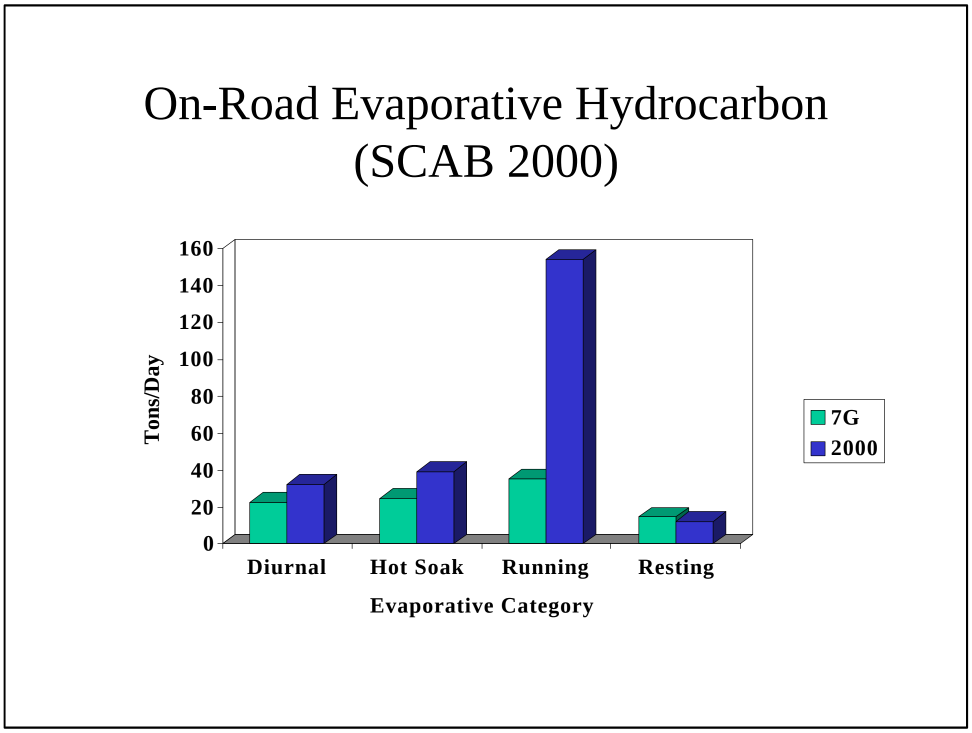
The EMFAC2000 model predicts significantly higher evaporative emissions compared to MVEI7G (See Figure 3). In the SCAB in 2000, greater than 140 tons per day increase in evaporative hydrocarbons is estimated. The bulk of this increase (85%) is attributable to changes to running loss estimates (119 tons per day). Another 10% is attributable to increases in hot soaks. The changes to running loss estimates include the changes to the vehicle population discussed above, and are based on new test data recently generated by the Coordinating Research Council (CRC).

Hot Soak Emissions

Hot soaks are evaporative emissions that occur immediately after a trip due to fuel heating when a hot engine is turned off. In older vehicles with carburetors, these emissions were attributed to boiling of the fuel in the carburetor float bowl. Newer vehicles experience these emissions from fuel remaining in the engine manifolds when the engine is turned off.

In MVEI7G, the emission rates of catalyst-equipped vehicles were based on data which showed hot soak emissions to be considerably less than non-catalyst vehicles despite the fact that the emission standards were equivalent (2.0 grams per test, hot soak plus diurnal).

Figure 3. – Comparison of MVEI7G and EMFAC2000 Evaporative HC for 2000



Newer data indicate higher hot soak emissions, especially for older catalyst equipped vehicles. As an example, the average hot soak emission rate for non-catalyst passenger cars in MVEI7G was estimated as 3.9 grams per trip in the year 2000. In contrast, catalyst equipped vehicles were estimated to have hot soak emissions that were an order of magnitude less (0.34 grams per trip). In EMFAC2000, the latest test data produced somewhat lower results for non-catalyst passenger cars (2.8 grams per trip) and significantly higher emissions for catalyst-equipped cars (0.52 grams per trip).

Hot soaks are calculated in the model as a function of trips taken per vehicle per day. In the model, it was assumed that the number of trips taken by a vehicle each day diminished with vehicle age. This estimate ranges from a high of over six and a half trips per day when the vehicle is new to a low of about four trips per day at the end of the vehicle's useful life. The modification of the age distribution in EMFAC2000 results in a fifteen percent higher average overall trip generation rate for passenger cars resulting in more hot soak tons per day in the SCAB in 2000.

Running Losses

Running losses are evaporative emissions that emanate from hoses, fittings, or canisters, while the vehicle is being operated. They can either occur because fuel heating has caused the vapor generation rate to exceed the vehicle's capacity to control the vapors, or through permeation and leakage. In the CRC study mentioned above, modal (minute by minute) running loss test results were collected for 150 vehicles of varying ages and technologies. The results of the study showed that running losses have a strong dependence on engine operating time, with emissions increasing the longer the engine is running. This makes sense because engine time-on is directly related to fuel temperature.

In MVEI7G, running losses were modeled as a function of speed rather than time and near zero running emissions were assumed at higher speeds. The results of the CRC study suggest that running loss emissions can be as high or higher than exhaust hydrocarbon emissions. The MVEI7G and EMFAC2000 running loss emission rates are compared to the results of the CRC study in Table 5.

Table 5. – Average Running Loss Emission Rate Estimates (95^{o}F)

	Passenger Cars			**Light-Duty Trucks**		
Model Yr.	**CRC**	**7G**	**2000**	**CRC**	**7G**	**2000**
1971-1977	3.91	0.24	3.76	1.07	0.20	2.37
1978-1985	2.05	0.20	2.16	0.69	0.16	0.99
1986-1991	0.27	0.18	0.26	0.66	0.08	0.32

The change in the emission factors due to addition of these new data to previous test projects performed by the ARB and U.S. EPA account for the bulk of the proposed increase in the running loss portion of the evaporative inventory (85% of the 140 ton per day increase). The remainder of the increase is attributable to the inclusion of liquid leakers.

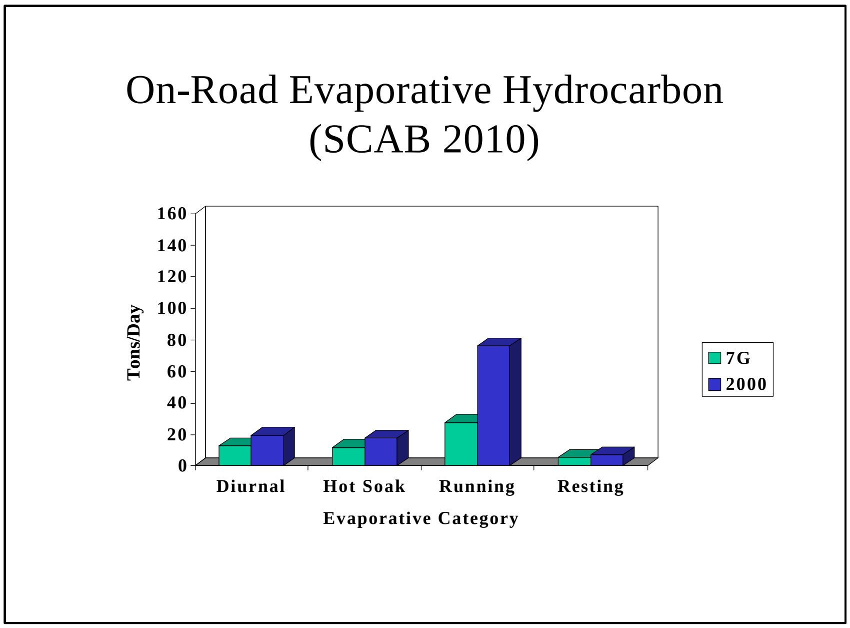
Liquid Leakers

As the name implies, liquid leakers are vehicles that actually drip fuel while running, parked, or both. Liquid leaks are not always obvious. In many cases, fuel does not leak unless the vehicle is running and the fuel is under pressure or being sloshed around in the fuel tank. The higher relative fuel pressures of fuel-injected vehicles compared to carbureted vehicles lead to more liquid leakers overall. MVEI7G did not include an estimate of emissions from this source because, in the past, vehicles with fuel leaks were routinely rejected from emission test programs due to safety considerations or repaired prior to testing. A recent test program performed by the Coordinating Research Council suggests that the population of these evaporative "gross polluters" is small, between zero and five percent of the fleet at any given time, yet their emissions can be as high as forty grams per mile. EMFAC2000 includes a specific estimate of the liquid leakers as a function of vehicle age and technology. In year 2000, 1.68% of the fleet is assumed to be liquid leakers with an average emission rate of 4.3 grams per mile.

Future Projections

In 1998, the Board adopted more stringent evaporative emission standards applicable to new vehicles sold in California. These "near zero" evaporative emission standards will reduce the inventory even more. In EMFAC2000, however, liquid leakers are assumed to remain prevalent in the fleet and are not assumed to be detected by either on-board diagnostic systems (OBD) or the Smog Check program that currently requires only a functional check of the gas cap and a visual check of the evaporative canister. Liquid leakers are projected to contribute 27 tons per day (23%) of all evaporative emissions in the SCAB in 2010.

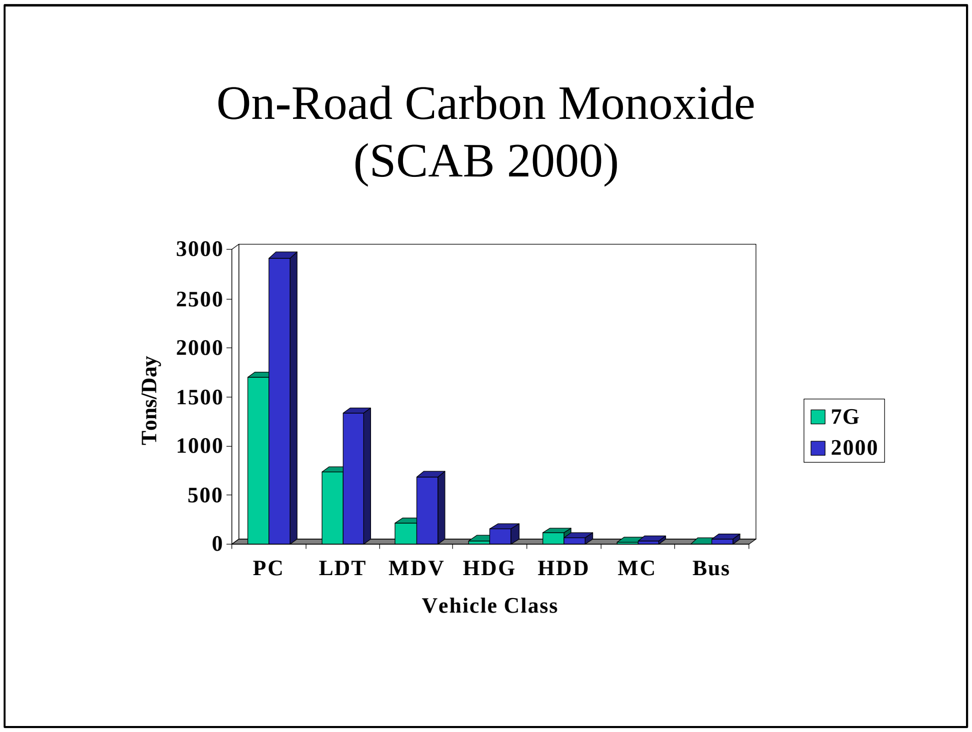
Figure 4. – Comparison of MVEI7G and EMFAC2000 Evaporative HC for 2010



Carbon Monoxide Exhaust Emissions

Carbon monoxide (CO) is also the product of incomplete combustion and is primarily attributed to gasoline-powered vehicles. Emissions of CO are also a strong function of operating temperature and CO episodes occur most often in winter months. The proposed EMFAC2000 inventory for CO in the SCAB would increase emissions by 2,400 tons per day in year 2000, nearly doubling the previous estimate. Three modifications to the model account for 65% of the increase in CO emissions. These are changes to the basic emission rates (+30%), adjustments to the speed adjustment factors (+20%) and the correction the fuel adjustment factors included in MVEI7G (+15%). Other changes including temperature correction and FTP to UC conversion are discussed in the Technical Support Document.

Figure 5. – Comparison of MVEI7G and EMFAC2000 CO for 2000



Emission Factors

In 1994, the ARB conducted an Inspection and Maintenance (I/M) evaluation program, in which selected vehicle owners due for registration renewal had their vehicles tested at the ARB's laboratory in El Monte. Over six hundred vehicles were tested during this program and the average emissions of this fleet were compared to the emissions estimates of the then current EMFAC7F model. It was found that the measured emissions of this fleet of vehicles were substantially higher than estimated by the model. As a result of this analysis, a high emitter correction factor was incorporated into MVEI7G that increased the emissions inventory for CO. Since no information was available for vehicles produced after 1993, this correction factor was not applied to newer vehicles.

In the development of EMFAC2000, additional test data, including the I/M evaluation data mentioned above, were used to update the emission factors. We suggest that the inclusion of this data results in a more realistic assumption of the presence of high emitting vehicles and makes the use of an explicit high emitter adjustment unnecessary. The incorporation of this new data resulted in an increase in CO of approximately 30% in the SCAB in the year 2000.

Speed Adjustment Factors

As discussed earlier, vehicles are tested over different driving cycles to model emissions as a function of average speed. CO emission rates vary significantly with driving pattern and speed and are most dramatically affected when hard acceleration and/or high engine loads are present in driving. EMFAC2000 incorporates new emission data generated using driving cycles representative of actual driving in Los Angeles. These data indicate that CO emissions increase during many types of typical driving. In contrast, MVEI7G adjusted CO emissions for varying average speeds in a manner that resulted in CO emissions being lower for nearly all driving patterns that varied from the average. The new speed adjustment factors in EMFAC2000 increase CO by 20%.

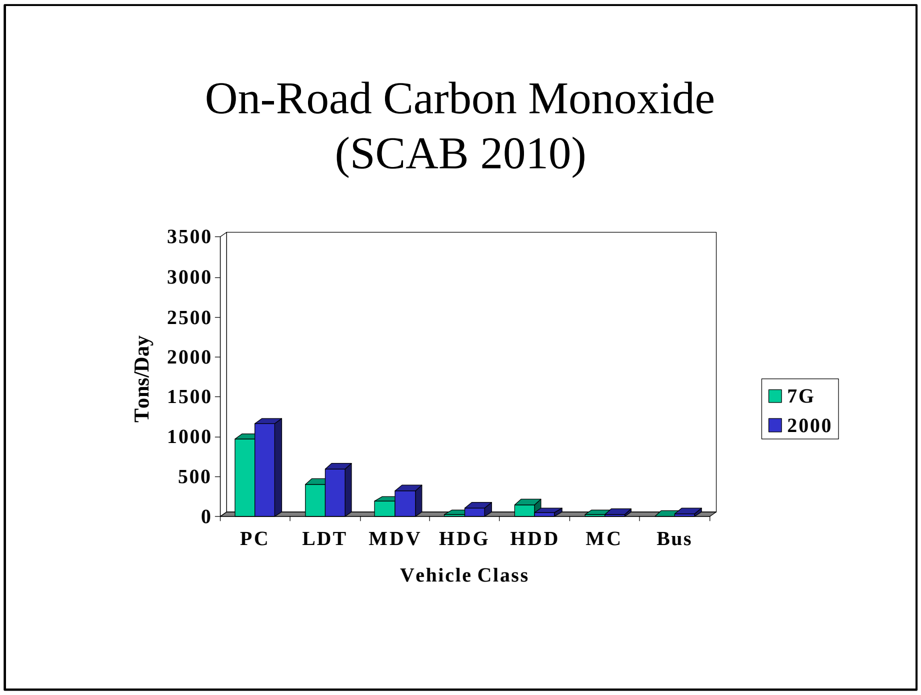
Fuel Adjustment Factor

The fuel correction factors in MVEI7G used to reflect the introduction of California Cleaner Burning Gasoline in 1996, incorrectly reduced CO emissions by 27%. This error was corrected in EMFAC2000, which includes a reduction of 11%. This correction to the model results in an increase in projected CO inventory of 15% in the SCAB in the year 2000. The benefits of RFG3 have not yet been incorporated into EMFAC2000.

Future Projections

The effect of recently adopted emissions standards that were not included in MVEI7G, such as LEV II, and more stringent motorcycle standards, will increase the rate of reduction of the CO inventory between 2000 and 2010. However, the resultant 2010 inventory of 2,300 tons per day is 32% higher than previously predicted by MVEI7G.

Figure 6. – Comparison of MVEI7G and EMFAC2000 CO for 2010

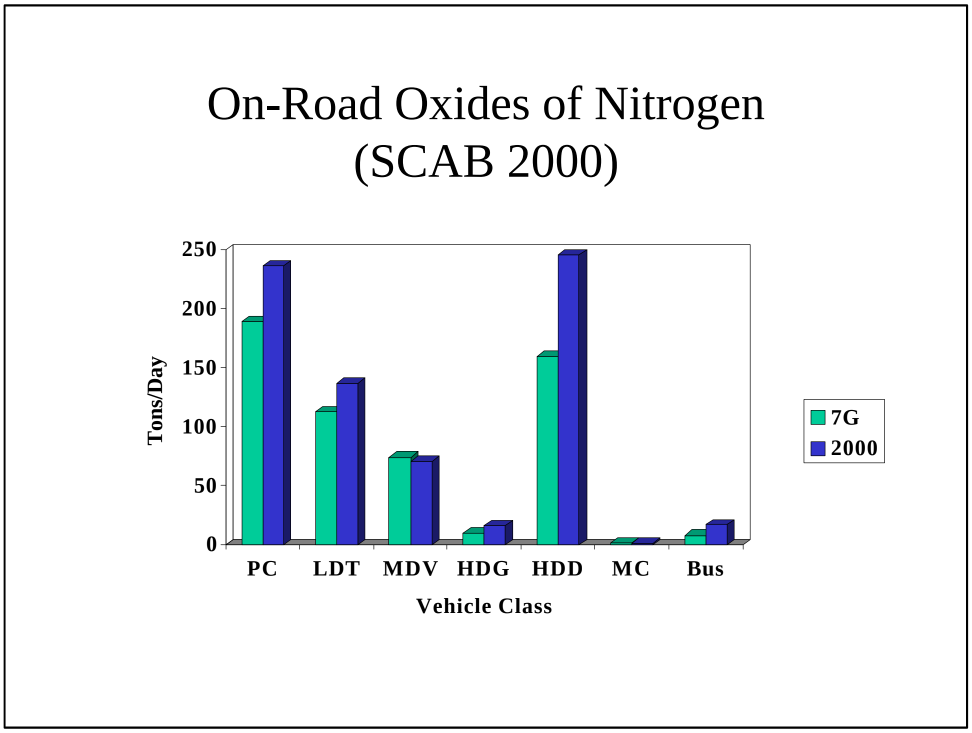


Oxides of Nitrogen Exhaust Emissions

Oxides of nitrogen emissions (NOx) are formed during high heat and pressure combustion when oxygen combines with nitrogen present in the air. Lean air-fuel ratios tend to promote more NOx formation because there is an excess of oxygen beyond what is needed for chemically correct combustion. Because of the high temperatures and lean air/fuel ratios associated with diesel cycle engines, diesel-powered vehicles tend to produce greater amounts of NOx than do gasoline-powered vehicles.

EMFAC2000 increases the on-road motor vehicle NOx inventory more than 160 tons per day (30%) in the SCAB in the year 2000. More than half of this increase, 86 tons per day, is attributable to heavy-duty diesel vehicles and "off-cycle" NOx. An additional 47 and 24 tons per day are due to increases in the emission rates of passenger cars and light trucks, respectively.

Figure 7. – Comparison of MVEI7G and EMFAC2000 NOx for 2000



Off-Cycle NOx

Heavy-duty engines, rather than the complete vehicle, are tested for development and certification on an engine dynamometer over a prescribed engine speed/load schedule. The dynamometer is used to simulate the typical modes of truck engine operation. This simulation does not fully represent many modes of operation, including constant speed freeway cruising. Emission factors gathered on the engine dynamometer are expressed as grams per brake-horsepower-hour (g/bhp-hr), or mass of emissions per unit of work performed.

In 1998, the U.S. EPA and the ARB discovered that the majority of heavy-duty diesel-powered engines produced between 1988 and 1998 were programmed to default to a fuel saving operating mode during periods of freeway cruise. This strategy increases emissions of NOx significantly from these engines. Because this operating mode is not present in significant amounts in the certification cycle, these emissions are referred to as "off-cycle". Enforcement action has been taken by the U.S. EPA and ARB against the engine manufacturers. However, the high emitting engines are still in use.

Unlike MVEI7G, EMFAC2000 relies upon the results of chassis dynamometer tests rather than engine tests with conversion factors, to develop basic emission rates for heavy-duty vehicles. The gram per mile emission rates gathered over the Urban Dynamometer Driving Schedule (UDDS) better represent the operation of these vehicles under "real world" driving conditions. The emission results from a total of fifty trucks tested over the UDDS were included in the EMFAC2000 update.

Although the UDDS lacks the extended cruises normally associated with off-cycle NOx emissions, some off-cycle operation is included in the cycle. It is likely that reliance upon the UDDS test results alone may result in an underestimation of the impact of off-cycle NOx. However, it is our opinion, as well as most members of the heavy-duty vehicle working group convened to address this issue, that it would be inappropriate to utilize the off-cycle NOx methodology developed by the U.S. EPA, as this correction is designed to be applied to chassis dynamometer results. The benefits of switching to a chassis-based emissions estimate for heavy-duty vehicles are believed to out weigh the uncertainty in the off-cycle NOx estimate.

Most of the remaining increase, 71 tons per day, is attributable to modifications to the emission rates of catalyst equipped passenger cars and light trucks. The increase in the basic emission rates of these classes of vehicles resulted from the addition of new test data and the modification of the deterioration rate, the increase in emissions as vehicles age. This modification to the model resulted in a 30% to 40% increase in NOx for these classes of vehicles. Staff will be undertaking an expanded test program to improve our understanding of heavy-duty vehicle emissions.

Future Projections

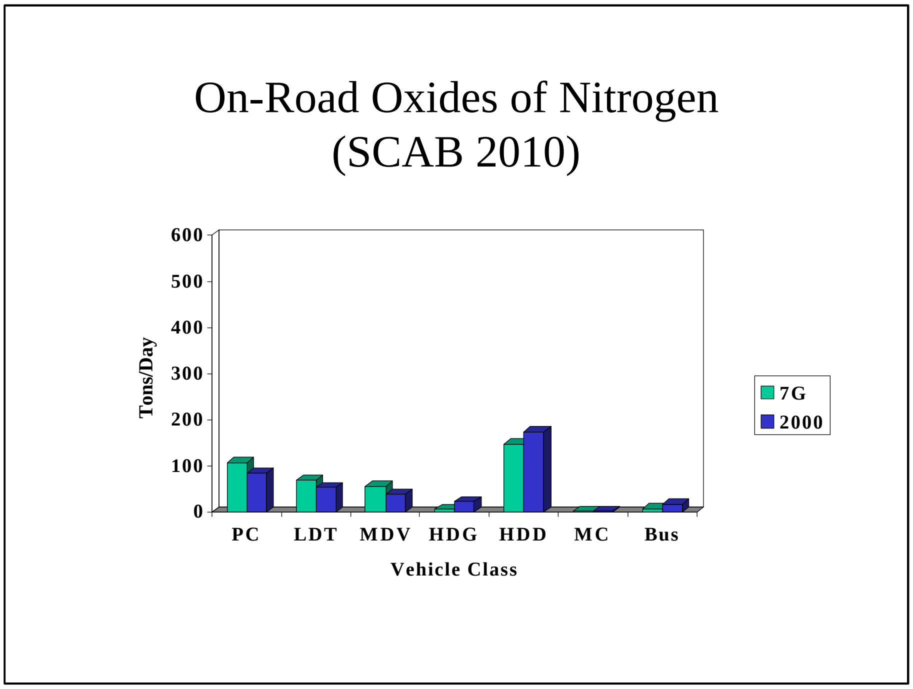
A settlement has been reached between the U.S. EPA, the ARB and engine manufacturers that will partially mitigate the impact of off-cycle NOx in the future. These and other standards previously adopted by the Board, some of which were not included in MVEI7G, are expected to reduce the NOx inventory in the SCAB by nearly 334 tons per day, over 40%, by the year 2010. The resultant inventory of 390 tons per day is consistent with that previously estimated by MVEI7G.

Particulate Matter Exhaust Emissions

Exhaust particulate matter are small, carbon and sulfur particles that are directly emitted as the product of incomplete combustion. Diesel fuel has a higher density and sulfur content compared to gasoline. As a result, diesel fueled vehicles contribute inordinately to the particulate emissions inventory.   Although only 3% of the vehicles in the SCAB are diesel powered, 37% of the directly emitted exhaust particulate matter, ten microns in diameter or less are attributable to these vehicles.

The estimate of particulate emission rates were updated for both gasoline and diesel powered vehicles in EMFAC2000. The majority of the difference is attributable to the addition of "smoky" vehicles and cycle adjustments (FTP to UC) for gasoline powered vehicles.

Figure 8. – Comparison of MVEI7G and EMFAC2000 NOx for 2010



INSPECTION AND MAINTENANCE

California's Inspection and Maintenance (I/M or Smog Check) program was instituted in 1984 requiring the periodic inspection of the emissions of on-road vehicles as a condition of registration renewal. In 1990, the program was improved to include a more comprehensive inspection, higher repair cost limits and more stringent standards.

In MVEI7G, substantial emission reductions were modeled for the 1984 program, 12% reduction in HC, 11% CO and 5% NOx, and even greater reductions for the 1990 program. Analyses of I/M evaluation program data from tests of over 1,000 vehicles conducted by the ARB now suggest a 15% reduction of HC exhaust, 9% for CO and 7% for NOx, are attributed to the 1984 program but little or no additional benefits were realized in the 1990 enhancements.

In the 1984 and 1990 I/M programs, no direct measurement was made for emissions of NOx. It was assumed in MVEI7G, that further enhancements to the I/M program would require dynamometer testing and direct measurement of NOx emissions, and that these enhancements would be fully implemented by 1996. EMFAC2000 reflects the delayed implementation date for many aspects of Smog Check II until the year 2000. By the year 2010, EMFAC2000 estimates the incremental benefits of Smog Check II to be 21% reduction of HC, 16% reduction of CO, and 18% reduction in NOx, over and above the two speed idle program.

EMISSIONS INVENTORY BY VEHICLE TYPE

The year 2000 calendar year inventory for California and the South Coast Air Basin is presented in Table 6 and for 2010 in Table 7.

Table 6. – On-Road Motor Vehicle Emissions Inventory for Year 2000 (TPD)

Statewide	**HCex**	**HCevap**	**HC Total**	**CO**	**NOx**	**PM10ex**
Pass Cars	429	384	813	6475	527	9
Light Trucks	192	142	334	3441	347	6
Medium Trucks	112	81	193	1833	179	4
Heavy-Gas	28	19	47	561	54	1
Heavy-Diesel	32	N/A	32	152	637	18
Bus	5	N/A	5	93	34	1
Motorcycle	9	10	19	83	3	0
Total	**807**	**636**	**1443**	**12637**	**1781**	**39**
South Coast AB	**HCex**	**HCevap**	**HC Total**	**CO**	**NOx**	**PM10ex**
Pass Cars	191	152	343	2915	236	4
Light Trucks	73	48	121	1333	137	2
Medium Trucks	41	29	70	683	71	1
Heavy-Gas	8	5	13	152	16	0
Heavy-Diesel	12	N/A	12	58	246	7
Bus	3	N/A	3	46	17	0
Motorcycle	3	3	6	29	1	0
Total	**331**	**237**	**568**	**5216**	**724**	**15**

*Numbers may not total exactly due to rounding.

Table 7. – On-Road Motor Vehicle Emissions Inventory for Year 2010 (TPD)

Statewide	**HCex**	**HCevap**	**HC Total**	**CO**	**NOx**	**PM10ex**
Pass Cars	149	167	316	2744	210	10
Light Trucks	76	106	182	1580	147	8
Medium Trucks	52	59	111	879	107	4
Heavy-Gas	18	17	35	309	56	0
Heavy-Diesel	21	N/A	21	108	408	13
Bus	6	N/A	6	68	35	1
Motorcycle	8	3	11	67	3	0
Total	**330**	**352**	**682**	**5755**	**966**	**36**
South Coast AB	**HCex**	**HCevap**	**HC Total**	**CO**	**NOx**	**PM10ex**
Pass Cars	59	60	119	1164	84	5
Light Trucks	27	32	59	595	53	3
Medium Trucks	19	21	40	332	39	2
Heavy-Gas	7	6	14	111	22	0
Heavy-Diesel	9	N/A	9	45	173	5
Bus	3	N/A	3	37	17	0
Motorcycle	3	1	4	27	1	0
Total	**127**	**120**	**247**	**2311**	**389**	**15**

*Numbers may not total exactly due to rounding.

APPENDIX A

MODIFICATIONS TO METHODOLOGY

Appendix A – Modifications to Methodology

Several modifications were made to the EMFAC2000 methodology in response to issues and concerns raised during, and after the December, 1999 workshop. Those changes that had the most significant effect on the inventory estimates are discussed below.

Table A1 – On-Road Motor Vehicle Emissions Inventory for Year 2000 (SCAB-tpd) Presented in December of 1999

	HCex	HCevap	HC Total	CO	NOx	PM10ex
Pass Cars	181	200	381	3234	192	3
Light Trucks	82	70	152	1674	117	2
Medium Trucks	67	50	117	1156	136	5
Heavy-Gas	13	8	21	257	26	2
Heavy-Diesel	13	N/A	13	51	539	21
Bus	1	N/A	3	1	10	0
Motorcycle	5	4	9	44	1	0
Total	362	332	694	6417	1021	33

Table A1 presents the emissions inventory estimates for the South Coast Air Basin as presented in the December, 1999 workshop which can be compared to those in the SCAB portion of Table 6 in the main report. Revisions to the EMFAC2000 methodology reduced emissions of HC, CO and NOx and PM by 31 tons per day, 1,225 tons per day, 293 tons per day and 18 tons per day, respectively, and evaporative emissions by 87 tons per day, in the year 2000.

VEHICLE POPULATION

In the December workshop, the estimated inventory was based on a vehicle population that was significantly higher than MVEI7G (+14% statewide). This difference was due to the inclusion of all vehicles classified by the Department of Motor Vehicles (DMV) as unregistered.

Based upon comments received regarding the appropriateness of this modification to the model, staff reviewed consecutive annual extracts from the DMV registration files. If an unregistered vehicle was not found to re-register within two years, it was dropped from the population estimates. The use of this criterion reduced the vehicle population associated with unregistered vehicles by 28% in EMFAC2000. A reduction in the vehicle population in turn reduces the “per vehicle” emissions inventory, (i.e., starts and evaporative emissions). The ARB has begun a statewide survey of unregistered vehicle operation that will allow a further refinement of this estimate in the near future.

STARTS PER VEHICLE PER DAY

The estimate of how often the average vehicle is started was also raised as an issue in the December workshop. The methodology used at that time relied upon instrumented vehicle data collected by the U.S. EPA in Baltimore, Spokane, and Atlanta. This data suggested that the average trip generation rate is 6.3 starts per vehicle per day and this frequency does not decline significantly as a function of vehicle age.

The comments received in response to this issue leveled criticism regarding the lack of California specific data and the lack of a declining assumption of engine starts per day as vehicles get older. Unable to resolve the differences between the federal data and the bases for starts included in MVEI7G, the constant 6.3 starts per vehicle per day estimate was replaced with the estimate included in MVEI7G. MVEI7G utilized a combination of instrumented vehicle and California travel survey data to derive a declining estimate of starts per day, from 6.5 for new vehicles to just below 4.0 for the oldest vehicles in the fleet.

Reverting to the former methodology reduced the number of starts by 32% percent in the SCAB in the year 2000. This modification resulted in a lower inventory associated with starts for all pollutants, and lower evaporative emission rates. This is especially true for hot soak emissions. Based on input from the U.S. EPA, staff also modified EMFAC2000 to assume no hot soak emissions for trips that are four minutes or less in duration, further lowering the evaporative inventory.

MODIFICATIONS TO EVAPORATIVE EMISSIONS

Several issues were raised regarding the treatment of evaporative emissions in EMFAC2000. Comments received, primarily from automobile manufacturers, led to revisions to the assumptions regarding the performance of future technology vehicles in controlling evaporative hydrocarbons.

In short, the estimates included in the December version of the model were considered too pessimistic. Cars designed to meet California's enhanced and near zero evaporative standards will utilize new, less permeable materials, and reduce the number of fittings. These design changes should lead to less frequent and less severe losses of evaporative control. In the current version of the model, a lower system failure rate, including liquid leaks, and lower emissions associated with multiple day events, are assumed for those vehicles certified to California's enhanced and near zero evaporative standards.

CHANGES TO HEAVY-DUTY VEHICLE INVENTORY

During the December workshop, representatives of the Engine Manufacturer's Association (EMA), questioned the appropriateness of the use of chassis dynamometer data instead of engine dynamometer data to develop heavy-duty vehicle basic emission rates. Of particular concern was the proposed use of the West Virginia, five mile route (WVU) cycle, a modified version of the Central Business District (CBD) cycle, as a representation of "real world" heavy-duty vehicle driving.

As a result, a heavy-duty vehicle working group consisting of members of industry, government and academia, was formed to resolve issues and provide input to staff regarding the modeling of heavy-duty vehicles emissions in EMFAC2000. In these meetings, it was decided that the Urban Dynamometer Driving Schedule (UDDS) was more appropriate than the WVU cycle for emission factor development. The UDDS tends to produce a lower PM estimate and higher NOx than does the WVU cycle.

The group also suggested that the UDDS contained conditions which could be considered "off-cycle" to the engine dynamometer test, and that the use of the U.S. EPA derived off-cycle NOx correction factor would be inappropriate. The use of the UDDS and the exclusion of an external off-cycle NOx correction factor resulted in an inventory for heavy-duty trucks which is lower for both NOx and PM in comparison to the December version of the model.

The inventory estimates from the December workshop and the revised EMFAC2000 model are contrasted in the table below for the South Coast Air Basin.

Table A2. – Previous and Current Emissions Inventory for SCAB

	2000			2010		
Pollutant	**12/99**	**2000**	**% Change**	**12/99**	**2000**	**% Change**
Total HC	694	569	-18	370	246	-34
CO	6417	5216	-19	2298	2311	1
NOx	1021	724	-29	539	390	-28
PM10 ex	33	16	-52	20	15	-25

APPENDIX B

COMPARISON OF MVEI7G TO EMFAC2000

Appendix B

Table B1. - Year 2000

Air Basin	ROG 7G	ROG 2000	CO 7G	CO 2000	NOx 7G	NOx 2000	PM10ex 7G	PM10ex 2000
Great Basin	2.5	3.2	29.0	27.1	5.5	3.4	0.11	0.07
Lake County	2.3	5.6	21.6	47.4	3.0	4.7	0.04	0.10
Lake Tahoe	2.5	3.8	43.8	42.7	1.8	3.0	0.04	0.07
Mojave Desert	31.3	30.7	269.3	277.7	56.6	32.5	1.30	0.60
Mountain Counties	14.3	32.5	130.4	276.5	22.7	30.0	0.39	0.72
North Central	18.3	30.2	170.8	246.0	29.4	38.5	0.62	0.81
North Coast	13.6	27.9	166.9	238.0	22.8	33.1	0.37	0.82
Northeast Plateau	5.2	8.3	56.0	72.1	13.8	8.0	0.46	0.19
Sacramento Valley	72.0	117.1	595.9	1004.1	122.5	150.2	3.01	3.34
Salton Sea	23.8	24.1	211.1	226.5	47.6	27.9	1.24	0.57
San Diego	89.6	120.7	780.5	1049.1	125.2	143.2	2.26	3.18
San Francisco	176.7	248.1	1603.6	1829.9	247.2	263.1	3.53	5.75
San Joaquin	111.3	161.3	975.0	1563.7	192.7	242.9	4.14	5.61
South Central	37.7	61.1	359.3	520.0	59.0	77.8	1.02	1.46
South Coast	321.4	569.0	2794.7	5215.8	554.3	723.6	12.94	15.79
Statewide	923	1443	8208	12637	1504	1782	31	39

Table B2. - Year 2010

Air Basin	ROG 7G	ROG 2000	CO 7G	CO 2000	NOx 7G	NOx 2000	PM10ex 7G	PM10ex 2000
Great Basin	1.1	1.7	20.4	13.1	3.8	2.3	0.07	0.08
Lake County	1.1	2.8	15.2	22.4	2.2	3.1	0.03	0.11
Lake Tahoe	1.1	1.9	28.7	17.6	1.3	1.9	0.03	0.07
Mojave Desert	18.8	17.5	197.7	147.6	45.7	19.8	1.04	0.63
Mountain Counties	6.6	17.2	90.1	133.5	16.5	18.8	0.29	0.70
North Central	7.8	16.9	100.8	123.2	21.4	20.8	0.44	0.71
North Coast	4.9	13.8	94.0	109.4	14.9	20.3	0.24	0.71
Northeast Plateau	2.4	4.0	38.8	32.4	10.7	5.6	0.30	0.20
Sacramento Valley	32.5	52.7	382.0	439.8	94.9	77.7	2.08	2.88
Salton Sea	10.5	12.9	145.9	120.2	41.0	19.2	0.92	0.56
San Diego	42.8	51.9	493.0	454.1	89.6	68.2	1.60	2.92
San Francisco	74.0	141.2	872.3	898.0	154.7	148.8	2.27	5.10
San Joaquin	53.0	69.8	656.5	698.3	145.1	132.2	2.78	5.11
South Central	14.7	26.1	194.2	214.4	38.3	36.4	0.65	1.26
South Coast	144.5	246.0	1753.0	2310.6	391.6	389.7	8.73	15.23
Statewide	416	676	5083	5735	1072	965	21	36

*Numbers may not total exactly due to rounding.